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Research Article

The effects of household and community context on mortality among children under five in Sierra Leone: Evidence from the 2013 Demographic and Health Survey

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Abstract

BACKGROUND
Sierra Leone in sub-Saharan Africa had one of the highest under-five mortality rates in the world in 2016: 114 deaths per 1000 live births. Previous studies have mainly focused on examining individual risk factors of child mortality in the country, without examining micro and macro levels of risk factors simultaneously.

OBJECTIVE
This study examines the effect of household and community context on the risk of dying for children under five in Sierra Leone.

METHODS
We use data from the 2013 Sierra Leone Demographic and Health Survey (SL DHS) to estimate the probability of dying, and examine mortality determinants using discrete-time event history analysis in a multilevel framework.

RESULTS
We find that individual child characteristics and mother- and community-level factors simultaneously affect the risk of child mortality. The substantial clustering of communities with high risk of mortality identified in the Eastern region indicates that children residing in the region have a higher risk of mortality than those in other regions. Further, the results suggest the need for targeted area interventions.

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CONCLUSIONS
We provide evidence suggesting that policymakers should focus on assisting mothers through family planning programmes to promote longer birth intervals, increased coverage of health services for mothers and children, and targeted interventions to reduce child mortality in the most affected regions of Sierra Leone.

CONTRIBUTION
We contribute recent evidence of determinants of child mortality in Sierra Leone from SL DHS 2013, including mother and community factors in a multilevel framework.

1. Introduction

The 2015 Millennium Development Goals report showed global declines in under-five mortality rates by more than half during 1990–2015, from 90 deaths to 43 deaths per 1000 live births (United Nations [UN] 2015). However, the significant decline in under-five mortality has not happened equally in all regions, particularly in sub-Saharan Africa and Oceania. The under-five mortality rate in sub-Saharan Africa was 86 deaths per 1000 live births in 2015, contributing "half of the burden of the world's under-five deaths" (UN 2015: 33). The UN predicts that the number of live births and the size of the under-five population will increase substantially over the coming decades in sub-Saharan Africa (UN 2015). This means that the number of deaths among children under the age of five in the region will increase if reductions in mortality cannot keep pace with population growth.

A number of studies have investigated child mortality in sub-Saharan African countries, with a degree of agreement on some determinants of child mortality. Proximate determinants such as child characteristics, maternal factors, and breastfeeding have shown expected associations with child mortality (Bado and Susuman 2016; Charmarbagwala et al. 2004; Omariba 2007). However, heterogeneity has also been found in studies of other determinants. A meta-analysis that includes child mortality studies in sub-Saharan African countries identifies mixed effects of birth order on child mortality, indicating that the effect of birth order is not fully understood (Charmarbagwala et al. 2004).

Besides the proximate determinants, studies have identified various socioeconomic factors at the individual, household, and community levels that can be important determinants of child mortality. Prior studies have shown heterogeneous effects of mother's education, socioeconomic status, and family structure on child mortality across countries in sub-Saharan Africa (Anyamele, Ukawuilulu, and Akanegbu 2017; Bado and Susuman 2016; Charmarbagwala et al. 2004; Ickowitz 2012; Lay and

Robilliard 2009). Several studies find that the death of the previous child increases mortality risk for the index child, suggesting the existence of shared frailty among children from the same mother (Charmarbagwala et al. 2004; Houle et al. 2013; Omariba 2007). Country-specific studies have also shown that mother's religion, tribe, occupation, mother's HIV status, housing condition, and access to drinkable water and electricity can affect child survival (Adedini et al. 2015a; Antai et al. 2009; van de Poel, O'Donnell, and Doorslaer 2009). The heterogeneity in results for sub-Saharan Africa suggests the need to better understand country-specific determinants in order to provide evidence to develop public health policy interventions.

The growing interest in clustering and disparities in child mortality across social groups and regions has led scholars to extend their studies to identify the contextual factors attributable to the phenomena. Studies have found disparities in child mortality between urban and rural areas in sub-Saharan Africa as a result of differences in living conditions (Anyamele 2009; van de Poel, O'Donnell, and Doorslaer 2009; Lay and Robilliard 2009). A study in Nigeria indicates that socioeconomic determinants at the community level explain variation in child mortality across regions, while individual-level characteristics including child and maternal factors explain variation in infant mortality in the country (Adedini et al. 2015b). Compelling evidence suggests the importance of considering both individual and contextual factors in examining determinants that explain variation in child mortality across social groups. The inclusion of contextual factors in examining child mortality determinants provides opportunities to identify possible social structures and community ecologies that affect child mortality. Furthermore, the possible existence of child mortality disparities across population groups also demonstrates the need to apply appropriate methods that can take into account dependency of observations to produce correct estimates in child mortality determinants.

We note several gaps from previous studies on sub-Saharan Africa. To our knowledge, few studies have simultaneously examined the effects of individual and contextual factors on child mortality and applied appropriate statistical methods to incorporate heterogeneity in child mortality across households and population groups. Despite countries in the western region of sub-Saharan Africa having among the highest child mortality rates in the world, mortality determinants in the region are relatively understudied. Therefore, this study contributes recent evidence about child mortality determinants in a country in the western region. We selected Sierra Leone because only a few studies have examined child mortality in the country. Sierra Leone has one of the highest child mortality rates in the world, at 114 per 1000 live births in 2016 (UNICEF 2017). With children under age five constituting 13.3% of the total population (UNFPA Sierra Leone 2018), a large number of children in the country are at risk of dying if these health issues persist in the country.

2. The Sierra Leone context

Sierra Leone in West Africa is divided into four administrative areas: the Western, Northern, Eastern, and Southern regions. The total population in 2015 was about 7 million, with almost half of the population living in rural areas (UNFPA Sierra Leone 2018). It is a Muslim-majority country, with Muslims comprising 78% of the population, followed by 21% Christian and 1% other religions (UNFPA Sierra Leone 2018). Muslims in this country typically blend Islamic and traditional African religious practices (Kallon and Dundes 2010). The major ethnicities are Mende, Temne, Limba, and Creole. The Human Development Index categorises the country as low human development, with an average 3.1 years of schooling, total life expectancy at birth of 50.9, and an estimated 56.6% of the population living below the poverty line in 2014 (United Nations Development Programme [UNDP] 2015).

A study shows that in terms of child health status, the main causes of death among children under five in Sierra Leone are preventable causes, such as prematurity and delivery complications for neonates and infectious diseases (Liu et al. 2012). The Ebola Virus Disease (EVD) has been considered a major threat to child health in Sierra Leone, due to increased child mortality and suggested significant declines in life expectancy in 2014 (Helleringer and Noymer 2015). The health system in the country is characterised by limited capacity to provide adequate health services to improve child survival. The civil war from 1991 to 2002 destroyed a substantial part of the health infrastructure and had long-term impacts on the government health system's ability to provide better health facilities (Wakabi 2010; McFerson 2012). Although the Sierra Leone government has implemented free health care for mothers and children since 2010, the policy has not led to a decline in maternal and child mortality. It has been suggested that the policy does not necessarily reduce the transport cost barrier that deters beneficiaries from accessing health services (Kanu, Tang, and Liu 2014; Edoka et al. 2015). Furthermore, a shortage of equipment, drugs, and health workers to implement the policy has an effect on the equal distribution of health services across communities (Kanu, Tang, and Liu 2014; Vallières et al. 2016).

3. Theoretical framework

Mosley and Chen (1984) established a theoretical framework that illustrates how socioeconomic determinants at the individual, household, and community levels operate through proximate determinants to affect the risk of dying among children in developing countries. Based on this conceptual framework, this study will examine determinants of child mortality in Sierra Leone at three levels: (1) child characteristics and maternal factors, (2) mother and household factors, and (3) community factors.

The explanation of the effects of contextual factors on child mortality rests on the assertion that the ecological context – public services, infrastructure, cultural setting, economic and political aspects – and the environmental situation are important factors determining health outcomes for individuals residing in a community (Earls and Carlson 2001; Galster 2008). The differences in contextual factors across communities create disparities in health outcomes across population groups, including differences in child mortality (Sastry 1997a). Ignoring the ecological context, such as the effect of household and community factors on health outcomes, can lead to an overstatement of the effect of individual factors in determining health outcomes (Diez-Roux 1998; Sastry 1997a). This underscores the importance of contextual factors and suggests the need for contextual or multilevel studies in order to provide both accurate estimates about the effect of health determinants at the individual and contextual levels and explanations of the variation in health outcomes across population groups (Diez-Roux 1998).

4. Research aims

This study aims to examine the effect of household and community context on the risk of dying for children under five in Sierra Leone. We investigate variation in child mortality across regions and population groups. The study applies multilevel modelling to account for unobserved heterogeneity and dependency (shared frailty) among observations in order to provide reliable estimates of the effects of determinants at the individual, mother or household, and community levels on variation in child mortality. The study aims to contribute recent evidence about determinants of child mortality in Sierra Leone.

5. Methods

5.1 Data sources

We use data from the 2013 Sierra Leone Demographic Health Survey (SL DHS).[3] The survey sample was selected through a stratified sampling with two stages: (1) selection

[3] In additional analyses we also examine determinants of child mortality using SL DHS 2008. The model results show different effects of certain covariates on the risk of child mortality from 2008 and 2013. However, the quality of under-five mortality reporting between the two surveys is very different. The 2008 SL DHS significantly underreported under-five mortality events in the period 2004–2008 (SSL and ICF

of the primary sampling units (PSUs), and (2) selection of 22 households from each PSU. As a result of the sampling design, data from the DHS is consistent with a multilevel or hierarchical structure, with children's information nested within mothers or households, and mothers' information nested within PSUs. We restrict the analysis to mortality risks among children born in the five years prior to the survey to reduce potential bias regarding omission of child death records. In total, this study includes information from 8,584 women in 2013, who provide information on 12,166 births.

We also use a global positioning system (GPS) dataset from the SL DHS 2013 that provides information about the latitude and longitude of PSUs. The data is available from the Spatial Data Repository on the DHS Program website [http://spatialdata.dhsprogram.com/home]. We use the GPS datasets to map the spatial distribution of child mortality risk.

5.2 Measurements

Our outcome of interest is the hazard of dying among children under five at age intervals 0, 1–5, 6–11, 12–23, and 24–59 months. We apply this age interval classification to reflect the hazard of dying in the neonatal period, post-neonatal period, and childhood period. These age intervals have been used previously (Pebley and Stupp 1987) to account for the effect of breastfeeding on the risk of mortality among children under five. The selection of potential explanatory variables is based on Mosley and Chen's theoretical framework, along with prior evidence from the literature; we do not use any step-wise regression techniques. We also examine potential multicollinearity issues based on variance inflation factors. We categorize potential explanatory variables into three levels according to the hierarchy of the data: child characteristics and maternal factors at the first level, mother/household characteristics at the second level, and community characteristics at the third level. At the child level we examine the effect of birth order, sex of child, single or multiple birth, child's size at birth, mother's age at child's birth, preceding birth interval, succeeding birth interval, breastfeeding status, and survival of previous child. At the mother/household level we include mother's religious affiliation, parity, marital status, education level, and wealth index. The wealth index in this study uses the DHS categories and definition, which is a combined measure of a household's cumulative living standard (Rutstein and Kiersten 2004). We define the community in this study as each survey's PSU. We aggregate individual-level data to derive community values for each characteristic. At the community level we include type of PSU or community (urban or rural), region where

International 2014). Given issues of differential data quality and comparability, we focus our presentation on the 2013 results, but provide the 2008 results in the Appendix for the interested reader.

the PSU was located, ethnic diversity categorised as (1) homogenous if the Temne or Mende ethnicities constitute >50% of total population in a community and (2) heterogeneous if those ethnicities are ≤50% in a community, the proportion of deliveries assisted by skilled delivery attendants, and the prevalence of diarrhoea. We include the sampling weights to derive the community covariates.

We define the covariates at the child level as proximate determinants through which mother-level and community-level characteristics could influence child mortality risk. All covariates, with the exception of the succeeding birth interval, are time constant and assumed to have the same effect on the risk of dying in each age interval. In general, the succeeding birth interval is more than 9 months; therefore, we assume the succeeding birth interval only affects children in the age intervals 12–23 months and 24–59 months. To account for the effect of the succeeding birth interval on the risk of dying of the index child during a certain interval, the birth must have occurred before the beginning of the age interval of the index child, and the index child must be alive at the beginning of the interval. This concept is applied to address the problem of reverse causality for the duration of the birth interval (Pebley and Stupp 1987). All the covariates are formed as categorical variables.

5.3 Statistical analysis

We use discrete-time event history analysis in a multilevel framework to estimate children's risk of dying by covariates at the three levels. The event in this study is a child's death. The length of time represents how long children survive before death occurs. Time in this study is treated as discrete to more accurately reflect the data-generating process due to recall bias, as the age at death does not represent the exact date when the child died. Further, in SL DHS 2013 there was considerable heaping of age at death because the number of deaths at age 12 months was double that of deaths at age 11 months and three times higher than deaths at age 13 months (SSL and ICF International 2014). These data issues may introduce bias in mortality estimation and distortion in mortality trends. Therefore, we treat time as discrete to reduce the effect of the age heaping phenomenon because using discrete time smooths the mortality pattern, as opposed to using single age, which will inflate mortality at a particular age, especially 12 months.

To perform discrete-time survival analysis, the observations in this study are expanded to as many observations as contribute to survival time. For example, if a child dies or is censored at age interval 12–23 months, the child will contribute survival information at each of intervals 0, 6–11 months, and 12–23 months. Therefore, we expand two new observations for the child to account for the child contribution to providing information at those three age intervals. The response variable is 0 for the child observations at intervals 0 and 6–11 months because the child still survives at these age intervals. The response variable for the child observation at age interval 12–23 months is 1 if the child dies during the interval. Otherwise, the response is 0 if the child survives at interval 12–23 months. We use maximum likelihood to estimate the parameters for the corresponding model (Allison 1982). Interval censoring is applied in this analysis. It is assumed that the value for each explanatory variable is measured once in each discrete-time unit.

The three-level hazard model in this study can be written as follows:

$$h(t_{aijk}) = h_0(t_a)\exp\left(b_1^T x_{ijk} + b_1(t_{aijk})z_{ijk} + v_k + \mu_{jk} + e_{ijk}\right),$$

where t_{aijk} is the time to death or censoring at age interval a for subject i from mother j in community k, $i = 1, \ldots., n_i, j = 1, \ldots.., I, k = 1, \ldots, I$; $h_0(t_a)$ is the baseline hazard at age interval a; b_1^T is a set of estimated coefficients for the characteristics x_{ijk} that are assumed to have a fixed effect on the risk of dying in each age interval a; b_1 is a set of estimated coefficients for characteristics z_{ijk} that are assumed to have different effects in each age interval a; v_k is a random effect for community k; μ_{jk} is a random effect for mother j in community k; and e_{ijk} is the residual for individual i from mother j in community k. The random effect (frailty) at the mother and community levels represents unmeasured and unmeasurable effects at each level on the risk of mortality.

In complementary log-log form the model can be written as follows:

$$\log\left[-\log\left(1 - h_0(t_a)\right)\right] = b_1^T x_{ijk} + b_1(t_{aijk})z_{ijk} + v_k + \mu_{jk} + e_{ijk}.$$

We compare model fit using the likelihood ratio test. All statistical analyses were performed using STATA 14.0. We also use GPS of sample cluster locations to map the distribution of the estimated hazard for each community according to the predicted conditional hazard from our modelling. ArcGIS Software version 10.3.1 was used for the mapping.

As the survey design results in a multilevel data structure due to the sampling design, dependency among observations (shared frailty) from the same group of the population may violate the assumption of independent observations. We use multi-level regressions to allow for correlation in mortality risks for children in the same household and community. The models are developed first by including the potential explanatory variables from child, mother, and community characteristics separately; to build the final model the child, mother, and community-level characteristics are then added sequentially. To model these shared environments we include random intercepts for the mother/household and community when it improves model fit. We summarize these shared frailties using the intraclass correlation coefficient (ICC). The ICC represents the extent of clustering in child mortality at the mother and community levels. The ICC at the mother level is defined as the proportion of mortality hazard variation across different mothers and as the expected correlation between the hazards of dying for children from the same mother. The ICC at the community level is then defined as the proportion of mortality hazard variation across communities and as the expected correlation between hazards of dying among children from different mothers but living in the same community. ICC values range between 0 and 1. An ICC value of 0 indicates no variation in hazard across groups at level 3 or level 2. ICCs are calculated using the following formulas:

Intraclass correlation level 2:

$$ICC\ mother\ level = \frac{\sigma^2_{mother}+\sigma^2_{community}}{\frac{\pi^2}{6}+\sigma^2_{mother}+\sigma^2_{community}}$$

Intraclass correlation level 3:

$$ICC\ community\ level\ = \frac{\sigma^2_{community}}{\frac{\pi^2}{6}+\sigma^2_{mother}+\sigma^2_{community}}$$

where $\frac{\pi^2}{6}$ is the variance of e_{ijk} and is assumed to be independent and identically extreme-value (Gumbel) distributed (StataCorp 2013).

6. Results

6.1 Child mortality pattern

We begin by presenting descriptive findings on child mortality. From a total number of 12,166 children under the age of five, 1,548 died before they reached age five. Mortality risk was highest for children <1 month and declined gradually over time, as illustrated by the Kaplan–Meier survival function (Figure 1).

Figure 1: Survival function for the relation between survival time and mortality

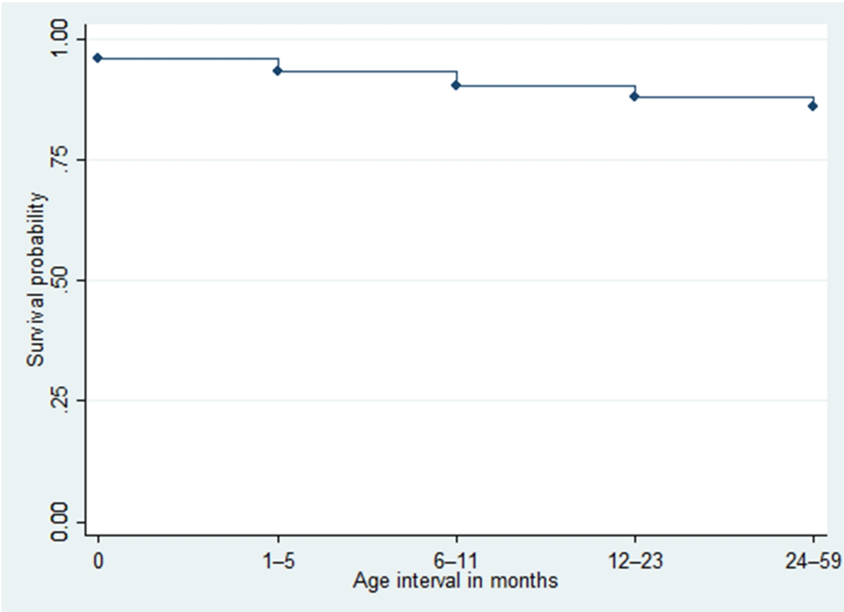


Table 1 presents the distribution of survival time of children into five age intervals, according to the SL DHS 2013. Table 1 shows the results of a bivariate analysis to test the distribution of survival time for each age interval across regions, where only survival time at age <1 month was significantly different across regions. However, aggregating survival times into regions may mask mortality patterns in small communities.

Table 1: Weighted percentage distribution of survival time by age group and region, SL DHS 2013

	Survival time status 2013									
	0 month		1–5 months		6–11 months		12–23 months		24–59 months	
Region	Alive (n=11,665)	Died (n=501)	Alive (n=11,218)	Died (n=325)	Alive (n=9,873)	Died (n=313)	Alive (n=8,458)	Died (n=240)	Alive (n=6,199)	Died (n=169)
Eastern	95.77	4.23	96.24	3.76	96.10	3.9	96.51	3.49	97.51	2.49
Northern	96.54	3.46	97.66	2.34	97.07	2.93	97.41	2.59	96.89	3.11
Southern	95.3	4.7	96.99	3.01	97.13	2.87	97.68	2.32	97.75	2.25
Western	93.76	6.24	97.04	2.96	96.97	3.03	96.88	3.12	97.5	2.5
p-value	*<0.001		0.263		0.101		0.379		0.491	

The distribution of observations by region for each characteristic is presented in Table 2. The characteristics are categorised into three groups: individual child-level, mother/household-level, and community-level characteristics.

Table 2: Weighted percentage distribution of sample for child-, mother-, and community-level characteristics by region

Explanatory variable	2013 Eastern (n=2,654)	Northern (n=4,770)	Southern (n=3,377)	Western (n=1,365)	p-value
Child-level characteristics					
Birth order					**<0.01
1	18.58	20.58	19.60	30.65	
2	17.52	17.60	17.15	25.13	
3	16.34	16.37	14.39	14.56	
4+	47.56	45.45	48.86	29.66	
Sex of child					0.18
Male	49.85	50.17	50.28	49.98	
Female	50.15	49.83	49.72	50.02	
Single or multiple birth					*0.03
Single	95.23	95.71	96.59	95.22	
Multiple	4.77	4.29	3.41	4.78	
Size at birth[a]					**<0.01
Small	18.98	16.77	12.91	17.46	
Average	49.92	28.13	46.42	27.95	
Large	27.74	50.65	35.06	44.82	
Missing	3.36	4.46	5.61	9.76	
Mother's age at child's birth					**<0.01
<20	16.95	17.21	16.88	17.52	
20–29	48.17	47.47	49.38	56.86	
30+	34.88	35.32	33.75	25.62	
Preceding birth interval months					**<0.01
First births	18.87	20.75	19.80	31.12	
0–12 months	0.97	0.51	1.08	2.04	
13–24 months	15.85	12.44	16.93	9.85	
25+ months	64.31	66.31	62.19	56.99	
Following birth interval months					**<0.01
0–12 months	0.72	0.41	0.77	1.43	
13–24 months	9.18	6.60	10.57	6.08	
25+ months	19.84	21.35	19.66	14.17	
No following birth	70.26	71.64	68.99	78.32	
Survival of previous child					**<0.01
First birth	18.58	20.58	19.60	30.65	
Previous child survived	64.99	65.98	66.88	57.21	
Previous child died	16.43	13.43	13.52	12.14	
Breastfeeding status					**<0.01
Never	6.27	3.07	3.75	4.96	
Still OR ever but not currently	91.04	93.49	92.60	90.26	
Missing	2.69	3.44	3.65	4.78	

Table 2: (Continued)

Explanatory variable	2013 Eastern (n=2,654)	Northern (n=4,770)	Southern (n=3,377)	Western (n=1,365)	p-value
Mother-level characteristics					
Religion					**<0.01
Islam	74.74	90.28	79.09	73.40	
Others	25.25	9.57	20.36	25.62	
Missing	0.01	0.16	0.55	0.98	
Total children ever born (parity)					**<0.01
1	11.53	14.22	13.25	23.79	
2–3	34.45	34.36	32.11	41.95	
4+	54.02	51.42	54.64	34.26	
Marital status					**<0.01
Married	87.30	88.11	83.44	59.35	
Single parent	11.50	10.55	11.93	27.97	
Living with partner	1.20	1.34	4.63	12.68	
Mother's highest education level					**<0.01
No education	70.41	73.95	72.92	43.62	
Primary	14.69	13.29	14.32	15.55	
Secondary or higher	14.90	12.76	12.76	40.83	
Wealth index					**<0.01
Poorest	28.16	20.03	35.93	1.85	
Poorer	26.52	24.90	21.72	1.11	
Middle	18.36	29.51	19.57	4.57	
Richer	17.10	21.86	16.93	16.99	
Richest	9.86	3.70	5.84	75.49	
Community-level characteristics					
Region of residence	21.81	39.21	27.76	11.22	
Place of residence					**<0.01
Urban	24.33	11.06	14.44	90.60	
Rural	75.67	88.94	85.56	9.40	
Ethnic diversity[b]					**<0.01
Homogenous	70.27	71.13	92.37	69.67	
Heterogeneous	29.73	28.87	7.63	30.33	
% deliveries assisted by skilled attendant					**<0.01
0–<25%	1.99	35.86	13.18	4.24	
25–<50%	12.51	27.17	17.19	6.26	
50–<75%	24.54	22.27	24.56	28.14	
≥75%	60.97	14.71	45.08	61.36	
Prevalence diarrhoea [c]					**<0.01
Low	40.18	23.83	45.95	30.50	
Middle	39.37	31.35	29.13	34.15	
High	20.45	44.82	24.92	35.34	

Note: ** p-value <0.01 and * p-value <0.05. a. Size at birth is a subjective report of the measurement of child by respondents. DHS categorise the measurement into very large, larger than average, average, smaller than average, very small, do not know, and missing. The categories were collapsed into four categories: large, average, small, and missing. b. Homogenous if the Temne or Mende ethnicities constitute >50% of total population in a community and heterogeneous if those ethnicities = <50% in a community. c. Prevalence of diarrhoea in a community is obtained by counting the number of children reported having diarrhoea in the last two weeks before the survey date. The prevalence is then categorised into three categories (low, middle, and high) according to three tertiles.

With respect to individual child-level characteristics, Table 2 illustrates that in 2013 the Eastern region had the largest proportion (19%) of children with small size at birth. More children (18%) were born in a short interval (0–24 months) after the previous birth in the Southern region than in other regions. A large proportion of children (11%) with a shorter succeeding interval (0–23 months) also lived in the Southern region. Regarding to the survival status of the previous child in a household, in the 2013 survey the Eastern region had the highest proportion (16%) of previous siblings who had died.

Turning to mother/household-level characteristics, Table 2 illustrates that mother's religious affiliation, parity, marital status, and highest education level differed significantly across regions. The majority of children were born to a mother with Muslim religion. A large proportion of children were born to women with high parity (more than four children) in all but the Western region. The largest proportion of children born to single mothers lived in the Western region. Most children were born to a mother with no education. Wealthy families were concentrated in the Western region, with 17% richer families and 75.49% richest families.

Table 2 also shows the distribution of children according to characteristics of the community where the children lived. According to the region of residence, the largest proportion of children lived in the Northern region. Most children lived in rural communities, except for children from the Western region who were mostly living in urban areas. The majority of children lived in homogenous communities, with more than 50% either Mende or Temne, or where there were combinations of the two ethnicities in the community. The literature shows there was a significant improvement in maternal health services in Sierra Leone in 2013 compared to 2008 (SSL and ICF International 2014). This is likely related to the 2010 government policy of providing free health services for mothers and children to reduce maternal and child mortality in the country (Jacobsen et al. 2012). Regardless of the improvement, there is disparity in the provision of maternal health services across region. Table 2 demonstrates that women in Eastern and Western regions had better access to maternal health services in terms of deliveries assisted by skilled delivery attendants compared to other regions. According to information about diarrhoea occurrence in the two weeks before the survey, a large proportion of children in the Northern region were living in a community with a high prevalence of diarrhoea compared to other regions.

6.2 Shared frailty among siblings and children residing in the same community

The following sections present findings from multivariate analysis for a model without covariates – the unconditional model. The model shows significant variation in the risk of child mortality across mothers ($\sigma^2_{mother} = 0.78, p < 0.001$). It also shows significant variation in the risk of child mortality across communities ($\sigma^2_{community} = 0.16, p < 0.001$). As the variance at each level also captures the total effect of unobserved covariates at the mother and community levels that affect mortality but are not included in the unconditional model, it is clear that child characteristics are not the sole influence on child mortality; rather there are mother and community characteristics that also independently influence the risk of mortality among children in Sierra Leone.

The model also shows that the ICC values for the unconditional model are greater than zero for children from the same mother (ICC = 37%) and children from different mothers but living in the same community (ICC = 6%). The ICC reveals shared frailty of mortality among siblings and children from the same community because they share common characteristics at the mother and community levels. It suggests that child mortality tends to cluster in specific families and communities.

6.3 Determinants of child mortality

Table 3 presents the associations between a child's risk of dying and child-, mother-, and community-level characteristics according to the model for the SL DHS 2013. At the child level, sex of child, single or multiple birth, size at birth, succeeding birth interval, and breastfeeding status are significantly associated with child mortality; the other characteristics are not associated with child mortality risk. Boys are more likely to die than girls. The risk of dying is higher among children from multiple births, with a hazard ratio more than three times higher compared to children born as a single birth. The hazard ratios decline gradually when a child is of average or large size at birth (HR = 0.59 and 0.54, respectively).

A short interval (0–11 months) between the index child and the succeeding birth increases the risk of dying by more than five times among children aged 12–23 months. A succeeding birth interval of 0–23 months increases the risk of dying two-fold among children aged 24–59 months. Breastfeeding status is a protective factor that reduces the risk of mortality by 90% for children who are still or were ever breastfed in their life compared to those never breastfed.

Examining mother characteristics (Table 3) shows that an increasing number of total children ever born was associated with an increased risk of dying. Children born to single mothers have their mortality risk increased by 43% compared to those born to married mothers. Mortality risk was higher for children born into the richest families, with a hazard ratio 66% higher than children from families with lower economic status. Mother's religious affiliation and education had no effect on the risk of mortality.

Table 3: Multilevel model of risk factors for under-five mortality in Sierra Leone, based on SL DHS 2013

	Multilevel model 2013			
Number of subjects	46,305			
Number of PSUs	435			
Number of mothers	8,300			
Log Likelihood	–5076.56			
Variance community level	0.17			
Variance mother level	0.82			
Explanatory variable	**Hazard ratio**	**p-value**	**95% CI**	
Child-level characteristics				
Age group				
0 months	0.36	**<0.01	0.21	0.60
1–5 months	0.31	**<0.01	0.18	0.52
6–11 months	0.35	**<0.01	0.21	0.59
12–23 months	0.31	**<0.01	0.18	0.54
24–59 months	0.24	**<0.01	0.14	0.42
Birth order				
1	–	–	–	–
2	1.02	0.96	0.46	2.30
3	0.86	0.72	0.36	2.01
4+	0.90	0.82	0.37	2.19
Sex of child				
Male	–	–	–	–
Female	0.83	*0.01	0.74	0.95
Single or multiple birth				
Single	–	–	–	–
Multiple	3.23	**<0.01	2.49	4.20
Size at birth[a]				
Small	–	–	–	–
Average	0.59	**<0.01	0.49	0.69
Large	0.54	**<0.01	0.45	0.64
Pregnancy history				
Mother's age at child's birth				
<20	–	–	–	–
20–29	0.93	0.50	0.75	1.15
30+	0.90	0.44	0.69	1.17
Preceding birth-interval months				
First birth	–	–	–	–
0–12 months	1.01	0.98	0.38	2.67
13–24 months	0.86	0.72	0.38	1.96
25+ months	0.55	0.15	0.24	1.24
Following birth interval for children at age 12–23 months				
0–11 months	5.75	*0.03	1.25	26.50
Following birth interval for children at age 24–59 months				
0–23 months	2.17	**<0.01	1.32	3.57
Survival of previous child				
Previous child died	1.21	0.06	0.99	1.46
Breastfeeding status				
Never	–	–	–	–
Still OR ever but not currently	0.10	**<0.01	0.08	0.13

Table 3: (Continued)

Mother-level characteristics				
Religion				
Muslim	–	–	–	–
Other	0.88	0.18	0.73	1.06
Total children ever born (parity)				
1	–	–	–	–
2–3	1.39	*0.02	1.05	1.83
4+	1.82	*0.01	1.19	2.79
Marital Status				
Married	–	–	–	–
Single parent	1.43	**<0.01	1.17	1.74
Living with partner	1.19	0.35	0.83	1.70
Mother's highest education level				
No education	–	–	–	–
Primary	1.08	0.43	0.89	1.31
Secondary or higher	0.88	0.25	0.71	1.09
Household wealth index				
Poorest	–	–	–	–
Poorer	1.06	0.57	0.86	1.31
Middle	1.26	*0.03	1.02	1.56
Richer	1.27	0.05	1.00	1.61
Richest	1.66	**<0.01	1.20	2.29
Community-level variable				
Region of residence				
Eastern	–	–	–	–
Northern	0.64	**<0.01	0.51	0.81
Southern	0.80	0.06	0.64	1.00
Western	0.74	0.06	0.54	1.01
Residence				
Urban	–	–	–	–
Rural	1.08	0.55	0.85	1.36
Ethnic diversity[b]				
Homogenous	–	–	–	–
Heterogeneous	0.72	**<0.01	0.59	0.87
% deliveries assisted by skilled attendant				
0–<25%	–	–	–	–
25–<50%	0.87	0.31	0.66	1.14
50–<75%	0.83	0.16	0.63	1.08
≥75%	0.59	**<0.01	0.45	0.78
Prevalence diarrhoea[c]				
Low	–	–	–	–
Middle	1.09	0.38	0.90	1.32
High	0.99	0.89	0.81	1.21

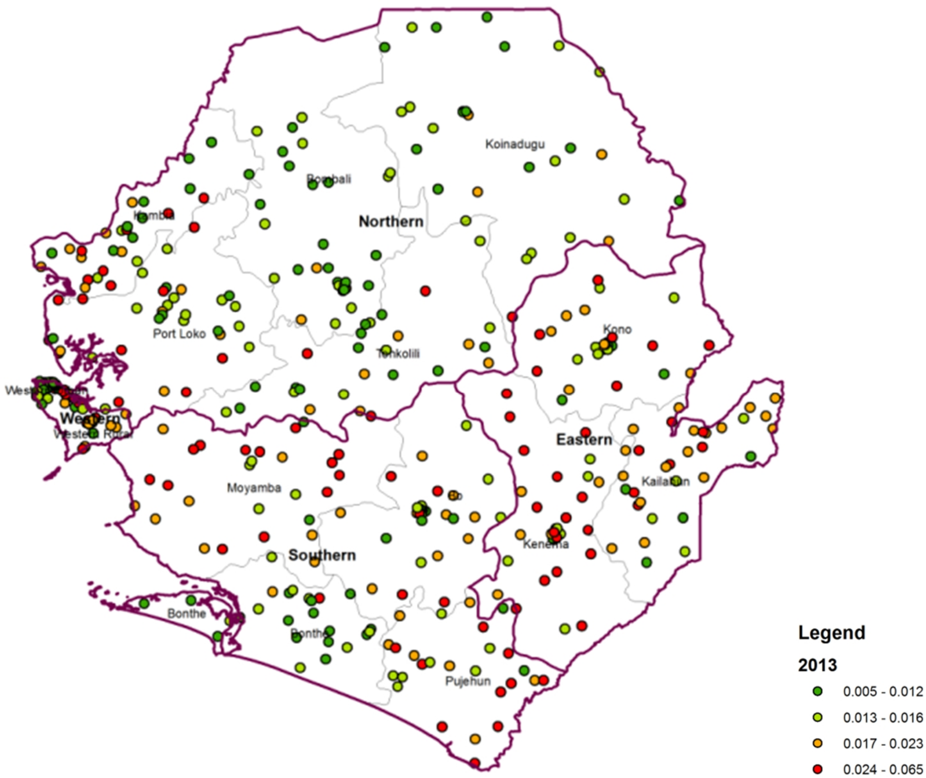
Note: ** p-value <0.01 and * p-value <0.05. a. Size at birth is a subjective report of the measurement of child by respondents. DHS categorise the measurement into very large, larger than average, average, smaller than average, very small, do not know, and missing. The categories were collapsed into four categories: large, average, small, and missing. b. Homogenous if the Temne or Mende ethnicities constitute >50% of total population in a community and heterogeneous if those ethnicities <=50% in a community. c. Prevalence diarrhoea in community is obtained by counting the number of children reported having diarrhoea in last two weeks before the survey date. The prevalence is then categorised into three categories (low, middle, and high) according to three tertiles.

At the community level (Table 3) the model shows significant differences in mortality risk according to region of residence. Children living in the Northern region have the lowest mortality hazard by 36%, relative to the Eastern region. Communities with heterogeneous ethnicities have a lower mortality hazard (28%) than more homogenous communities. Communities with proportions of >75% of births assisted by skilled attendants have the lowest mortality hazards (41%) compared to other communities with a lower number of assisted births. Residing in an urban or rural area and the prevalence of diarrhoea are not significantly associated with child mortality.

Figure 2 shows the predicted mean hazard of mortality for each PSU, from the model that is classified in four quintiles. The map shows that communities with a higher risk of mortality are distributed in the Eastern region.

Figure 2: Predicted mean hazard of under-five mortality by PSU in four quintiles for 2013

Plot mean hazard of under-five mortality in 2013 from Final Model



Source: Sierra Leone DHS 2013.

7. Discussion

We found that individual child-, mother-, and community-level characteristics simultaneously affect the risk of child mortality in Sierra Leone. Our study confirms the presence of regional variation in the risk of child mortality. Spatial mapping for the predicted hazard of child mortality also confirms that communities with high mortality risk tend to be clustered in the Eastern region. Our study also identifies shared frailty or risk of mortality among children from the same mother or in specific households, suggested by an ICC at mother level greater than zero.

Unobserved heterogeneity remained at the mother and community levels even after adjusting for all covariates. Future studies are needed to identify mother- or family-level factors not observed in this study in order to provide more information about the causes of mortality clustering in certain families. Factors at the mother or family level might be related to genetics and childcare practices (Sastry 1997b). Further investigation into the effect of environmental, climatic, geographical, and spatial factors (e.g., distance to public facilities) and community infrastructure (e.g., quality of health facilities) may help explain residual variation at the community and mother levels.

At the individual child level, our findings show that a birth interval of more than two years is a protective factor reducing child mortality, in agreement with other studies (Hobcraft, McDonald, and Rutstein 1985; Knodel and Hermalin 1984; Pebley and Stupp 1987). The insignificant effect of mother's age at birth and birth order on child mortality in this study is coherent with a study by Hobcraft, McDonald, and Rutstein (1985), which found that the effect of these variables did not persist after controlling for birth interval and mother parity.

At the mother level, we identified that higher parity increases the risk of child mortality, as found in previous studies (Knodel and Hermalin 1984; Kozuki, Sonneveldt, and Walker 2013). In line with Izugbara's (2016) findings using SL DHS 2008 data, children of single mothers had a higher risk of dying than those of married women.

Regarding household wealth index, we found that children from the richest families according to the wealth index have a higher risk of mortality than families with a lower wealth index. This finding is the opposite of that reported in a previous study using the SL DHS 2008 data, which concluded that children from richer families have higher survival (Izugbara 2016). In this study, mother's education level was consistently not associated with child mortality in Sierra Leone, with or without the inclusion of random intercepts at the mother and community level. This finding differs from a previous study on neonatal and infant mortality in Sierra Leone, which found that children of better-educated women have higher survival (Izugbara 2016). This study also identified an insignificant effect of mother's religious affiliation on the risk of child mortality. This finding differs from a previous study using SL DHS 2008, which found that children of mothers with other religions had a higher percentage of deaths compared to Muslim children (Davids, Sasuman, and Abduraghiem 2013).

The differing results for the effect of wealth index, education, and religion could be due to differential rates in underreporting of child deaths and different statistical approaches to examining these factors. Previous studies (Davids, Sasuman, and Abduraghiem 2013; Izugbara 2016) used regression techniques that assumed independent observations, while the present study applied survival analysis with multilevel modelling that included random intercepts at the mother and community levels to incorporate dependence in observations from the same mother and in similar communities. Moreover, the study by Izugbara (2016) only focused on analysing mortality in neonates and infants, while the present study includes children under five. This may indicate that those factors have a different effect on child survival during the neonatal period, infancy, and childhood; however, interactions between child age and mother's education, wealth index, and religion were not significant in this study. The effects of those factors may also vary by community. Further investigation is needed to provide greater understanding of how these factors may vary between communities, such as testing the different effects of wealth index by community.

A different categorisation of wealth index in this study compared to Izugbara (2016) is another possible explanation for the mixed results of the effect of wealth index on child mortality in Sierra Leone. The finding regarding the insignificance of wealth index may also indicate an error measurement of wealth index as a proxy to measure the relationship between socioeconomic status and child mortality. It has been noted that the household wealth index in DHS measurement may have a potential bias to urban measurement and to household size, resulting in inconsistent associations between socioeconomic status and child mortality (Charmarbagwala et al. 2014; Lay and Robilliard 2009). Therefore, identifying an appropriate proxy for socioeconomic status in further study can improve knowledge about how it affects child mortality.

A study on the effect of mothers' education on child mortality in sub-Saharan Africa provides a possible clue regarding the insignificant effect of mother's education observed in this study: Bado and Susuman (2016) suggest the insignificant effect of education may be a result of government programmes, in particular free health care for mothers and children, which reduce barriers to accessing health facilities and thus the disparity in child survival between educated and non-educated women. Moreover, it has been suggested that the effect of mothers' education level may vary across areas of residence, such as urban and rural (Bicego and Boerma 1993).

We found that children living in homogenous communities characterised by more than 50% of either Mende or Temne ethnicity have a higher risk of mortality than those in communities with heterogeneous ethnicity. In a homogenous community, people are more likely to share common norms and values, particularly related to health-seeking behaviours for mothers and children, and this may result in differences in child mortality between homogenous and heterogeneous communities. Studies on the causes of disease in Sierra Leone have found that parents of Temne ethnicity believe that spirits or external agents cause diarrhoea (McMahon et al. 2013). Also, women are prevented from breastfeeding by the belief that if the mother has sex while breastfeeding she will have 'bad milk' (Sharkey 2016). These studies provide insights into why the risk of child mortality can be higher in a homogenous community characterised by more than 50% of either Mende or Temne ethnicity.

Underscoring the importance of birth interval and parity, the present study highlights the need to focus on improving family planning in Sierra Leone to prevent child mortality by increasing birth intervals to more than two years and reducing high parity among women. The clustering of child mortality in certain families, communities, and in the Eastern and Southern regions also suggests the need to identify and prioritize interventions and target those most at risk.

This study has several strengths. By adjusting for unobserved factors using residual variances at the mother and community levels, we provided corrected estimates of the effect of covariates. This adjustment also enabled us to explain variation in the hazard of dying across regions and small population groups (PSUs), rather than simply examining the risk factors of under-five mortality in Sierra Leone. We were also able to simultaneously examine the effect of covariates from individual and community factors on children's risk of dying. We tried to reduce bias due to age heaping and misreporting age at death by applying discrete-time analysis. Although some variables have missing values such as size at birth and breastfeeding status, the effect of other covariates remained similar even after exclusion of size at birth and breastfeeding status variables from the model.

However, there are limitations to this study. One limitation of the survey is that it only includes birth histories from surviving mothers. As a result, the occurrence of deaths and characteristics of observations in this study cannot explain risk factors for children whose mothers died. Child survival is affected by parental death: a study shows that the death of the mother has the greatest effect on survival of children aged 2–5 months and even up to 10 years of age (Ronsmans et al. 2010). With regard to the important role of unobserved factors at the mother or family level in influencing child mortality in Sierra Leone, the risk of mortality among children whose mother or father has died can be very high. Maternal mortality in Sierra Leone is very high, with a lifetime risk of maternal death of 1 in 21 in 2015 (UNICEF 2015), so it is necessary to investigate the risk of mortality among children whose mother has died to obtain a fuller understanding of determinants of child mortality in Sierra Leone. Further, the potentially different effect of covariates in different communities was not tested in this study.

8. Conclusions

This study demonstrates that individual-, mother-, and community-level factors simultaneously affect child mortality in Sierra Leone. Our results highlight the need to investigate unobserved factors at the mother and family levels that may explain the clustering of mortality in certain families. We confirmed the presence of regional variation in the hazard of mortality and variation across communities. Substantial clustering of communities with high mortality risk was identified in the Eastern region, which indicates the need for targeted area interventions.

This study also suggests that further studies are needed to investigate child mortality risk in Sierra Leone due to variation at the mother or family level and the community level that remain unexplained by our models. Our study contributes recent knowledge about risk factors of child mortality in Sierra Leone. We provide evidence suggesting the need for appropriate family planning programmes to promote longer birth intervals, increased coverage of health services for mothers and children, and focused intervention that can reduce child mortality in the most affected regions of Sierra Leone.

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Appendix

Table A-1: Multilevel model of risk factors for under-five mortality in Sierra Leone, SL DHS 2008

	Model 2008			
Number of subjects	19,433			
Number of PSUs	351			
Number of mothers	3,715			
Log Likelihood	–1811.08			
Variance community level	0.26			
Variance mother level	0.75			
Explanatory variable	**Hazard ratio**	**p-value**	**95% CI**	
Child-level characteristics				
Age group				
0 months	0.33	**<0.01	0.15	0.70
1–5 months	0.38	*0.01	0.18	0.82
6–11 months	0.41	*0.02	0.19	0.88
12–23 months	0.29	**<0.01	0.13	0.65
24–59 months	0.25	**<0.01	0.11	0.58
Birth order				
1	–	–	–	–
2	0.38	0.24	0.08	1.91
3	0.55	0.48	0.10	2.89
4+	0.42	0.32	0.08	2.31
Sex of child				
Male	–	–	–	–
Female	1.17	0.14	0.95	1.45
Single or multiple birth				
Single	–	–	–	–
Multiple	4.09	**<0.01	2.59	6.46
Size at birth[a]				
Small	–	–	–	–
Average	0.78	0.10	0.58	1.05
Large	0.82	0.16	0.62	1.08
Pregnancy history				
Mother's age at child's birth				
<20	–	–	–	–
20–29	0.65	*0.01	0.46	0.91
30+	0.60	*0.02	0.39	0.92
Preceding birth interval months				
First births	–	–	–	–
0–12 months	1.15	0.88	0.19	6.78
13–24 months	1.50	0.63	0.30	7.56
25+ months	0.86	0.86	0.17	4.30
Following birth interval for children at age 12–23 months				
0–11 months	4.79	0.17	0.53	43.69
Following birth interval for children at age 24–50 months				
0–23 months	2.17	0.06	0.97	4.85
Survival of previous child				
Previous child died	1.65	**<0.01	1.20	2.27

Table A-1: (Continued)

Pregnancy history				
Breastfeeding status				
Never	–	–	–	–
Still OR ever but not currently	0.07	**<0.01	0.05	0.10
Mother-level characteristics				
Religion				
Muslim	–	–	–	–
Other	0.60	**<0.01	0.44	0.82
Total children ever born (parity)				
1	–	–	–	–
2–3	1.94	**<0.01	1.24	3.04
4+	3.22	**<0.01	1.63	6.36
Marital status				
Married	–	–	–	–
Single parent	1.10	0.59	0.78	1.56
Living with partner	1.26	0.20	0.89	1.78
Mother's highest education level				
No education	–	–	–	–
Primary	1.18	0.31	0.86	1.63
Secondary or higher	1.04	0.85	0.71	1.52
Household wealth index				
Poorest	–	–	–	–
Poorer	0.74	0.13	0.50	1.09
Middle	0.91	0.62	0.63	1.32
Richer	0.89	0.58	0.59	1.35
Richest	1.03	0.92	0.62	1.71
Community-level variable				
Region of residence				
Eastern	–	–	–	–
Northern	0.56	**<0.01	0.38	0.82
Southern	1.17	0.40	0.81	1.69
Western	0.83	0.42	0.54	1.29
Residence				
Urban	–	–	–	–
Rural	0.57	*0.01	0.39	0.84
Ethnic diversity[b]				
Homogenous	–	–	–	–
Heterogeneous	0.93	0.64	0.68	1.27
% delivery assisted by skilled attendant				
0–<25%	–	–	–	–
25–<50%	0.61	*0.01	0.41	0.90
50–<75%	0.85	0.43	0.56	1.27
≥75%	0.61	*0.03	0.38	0.95
Prevalence diarrhoea[c]				
Low	–	–	–	–
Middle	1.40	*0.04	1.02	1.92
High	1.40	*0.04	1.01	1.94

Note: ** p-value <0.01 and * p-value <0.05. a. Size at birth is a subjective report of the measurement of child by respondents. DHS categorise the measurement into very large, larger than average, average, smaller than average, very small, do not know, and missing. The categories were collapsed into four categories: large, average, small, and missing. b. Homogenous if the Temne or Mende ethnicities constitute >50% of total population in a community and heterogeneous if those ethnicities = <50% in a community. c. Prevalence diarrhoea in community is obtained by counting the number of children reported having diarrhoea in last two weeks before the survey date. The prevalence is then categorised into three categories (low, middle, and high) according to three tertiles.